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Effect of Frost on the Strength of Cement Mortar

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EFFECT OF FROST

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STRENGTH OF CEMENT MORTAR

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Howard Vanreed Maury

ENTITLED Effect of Frost on the Strength of Cement Mortar

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Effect of Frost on Cement-Mortar.

The object of this thesis is to find the effect of frost on the strength of cement mortar.

There is a difference of opinion among engineers as to the extent cement mortar is injured by freezing. Some think it should not be used for building purposes above ground in freezing weather; while others think the amount of injury done is too small to interfere with any undertaking. If cement mortar is not to be used in freezing weather its use in this latitude is limited to the period between April the first and November the first – a comparatively short time.

Mr. A. C. Hobart of the University of Illinois, for his bachelors' thesis, in the spring of 1897 made a large number of experiments on this subject, and deduced the conclusion that cement mortar was made stronger by freezing. Mr. Hobart stored his

unfrozen briquettes dry. It is known that briquettes stored in this manner are not under the most favorable conditions, and do not get their full strength as certainly as when stored under water, owing to the loss by vaporization of the water necessary for chemical action. Hence the probable explanation of his anomalous results is that his unfrozen briquettes were weakened by the vaporization of the water more than the frozen ones were weakened by freezing. So to eliminate this source of error in this thesis the unfrozen briquettes were allowed to stand under water until tested.

Cements and Proportions.

In conducting these experiments six cements were used, — three Portland and three natural. The Portlands were Alsen, Atlas, and Alpha; the naturals were Clarks' Utica, Rosendale, and Louisville Globe. These cements were chosen because they are often used in engineering work in this country.

The sand used was German standard. The grains are pure quartz, round with roughened surfaces.

The proportions used were: for the Portland cement, four to one; and for the natural cement, three to one. In all cases the proportions were measured by weight. These proportions were chosen because it was thought they represented practical conditions.

Mixing and Molding.

After the proper proportions of cement and sand had been weighed, they were thoroughly mixed dry on a slate slab; and then the proper amount of water was added, and the whole mixed and rubbed to a uniform consistency. The mortar was all mixed plastic, as it was thought that freezing would have a greater effect on plastic than on dry mortar. The mortar was at once put into molds. The molds were of the size recommended by the American Society of Civil Engineers.

All briquettes were hand moulded.

the mortar being rammed into place with the thumb, and then smoothed with a trowel.

Those briquettes to be frozen immediatly were placed out of doors in the molds. Briquettes were also placed out of doors after having set in a warm room for one hour, two hours, etc. Those briquettes which were kept in a warm room for comparison were covered with a damp cloth and allowed to set for about twenty four hours, when the molds were removed and the briquettes placed under water. Those briquettes which were placed outside were allowed to freeze for one week, then they were brought inside and placed under water taken from the city mains and left until tested.

Testing.

A Fairbank testing machine was used in determining the tensile strength. The weight was applied by a stream of fine shot running into a small bucket attached to the free end of the

scale beam. When enough shot had run into the bucket to break the briquette, the stream of shot was automatically cut off and the shot in the bucket weighed. This furnishes a very convenient and efficient way to test the briquettes and the probable error for each briquette would not be more than two pounds.

Tables I to VI contain the results.

TABLE I

Tests to determine the effect of freezing Portland cement mortar continually one week and then allowing it to stand in a warm room under water for three weeks.

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
	—ALSEN—		
unfrozen	152	4	
0 hr.	125	4	82 %
1 "	132	4	87
2 "	135	4	89
3 "	141	4	93
4 "	143	4	94
5 "	148	4	97
6 "	138	4	91
7 "	142	4	93
	— ALPHA —		
unfrozen	145	4	
0 hr.	117	4	81 %
1 "	128	4	88
2 "	129	4	88
3 "	135	4	93
4 "	134	4	93
5 "	130	4	90
6 "	136	4	87
7 "	132	4	91
	— ATLAS —		
unfrozen	159	4	
0 hr.	115	4	72 %
1 "	115	4	72
2 "	123	4	77
3 "	129	4	81
4 "	131	4	82
5 "	134	4	84
6 "	116	4	73
7 "	118	4	74

TABLE II

Tests to determine the effect of alternate freezing and thawing Portland cement mortar one week and then placing it in a warm room under water for one day.

— ALSEN —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	120	7	
0 hr.	86	3	72
1 "	100	3	83
2 "	106	3	88

— ALPHA —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	110	7	
0 hr.	32	3	29
1 "	46	3	42
2 "	74	3	67

— ATLAS —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	95	7	
0 hr.	18	3	19
1 hr.	60	3	63
2 "	70	3	73

TABLE III

Tests to determine the effect of continually freezing Portland cement mortar for one week and then allowing it to stand in a warm room one day under water.

— ALSEN —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	109	10	
0 hr.	82	3	75 %
1 "	82	3	75
5 "	73	5	67

— ALPHA —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	124	10	
0 hr.	62	3	50 %
1 "	66	3	53
5 "	63	5	51

— ATLAS —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	87	10	
0 hr.	70	3	80 %
1 "	73	3	84
5 "	85	5	98

TABLE IV

Tests to determine the effect of alternate freezing and thawing Natural Cement Mortar for one week and then placing it in a warm room for one week under water.

– UTICA –

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	90	3	
0 hr.	did not retain	3	
1 "	shape when put	3	
2 "	in water.	3	
3 "		3	
5 "		4	

– ROSENDALE –

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	50	4	
0 hr.	partially retained	3	
1 "	shape when	3	
2 "	put in water	3	
3 "		3	
5 "		3	

– LOUISVILLE GLOBE –

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	66	4	
0 hr.	75	3	120 %
1 "	48	3	73
2 "	45	3	68
3 "	50	3	75
5 "	45	3	68

TABLE V

Test to determine the effect of continually freezing natural cement mortar for four days then placing it in a warm room for three weeks under water.

— UTICA —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	107	5	
0 hr.	30	3	28 %
1 "	40	3	37
2 "	33	3	31
3 "	55	3	51

— ROSENDALE —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	50	5	
0 hr.	51	3	102 %
1 "	72	3	144
2 "	80	3	160
3 "	87	3	174

— LOUISVILLE GLOBE —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	73	5	
0 hr.	147	3	200 %
1 "	142	3	195
2 "	140	3	192
3 "	144	3	197

TABLE VI

Test to determine the effect of continually freezing natural cement mortar for four days then placing it in a warm room for thirty-six hours under water.

— UTICA —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	39	3	
0 hr.	did not retain	3	
1 "	shape	3	
2 "	0	3	
3 "	0	3	

— ROSENDALE —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	22	3	
0 hr.	did not retain	3	
1 "	shape	3	
2 "	12	3	54 %
3 "	14	3	63

— LOUISVILLE GLOBE —

Age when frozen	Average lbs. per sq. in.	No. Br.	Ratio-frozen to unfrozen
unfrozen	45	3	
0 hr.	28	3	62 %
1 "	30	3	66
2 "	31	3	69
3 "	35	3	77

Discussion.

The briquettes that were frozen were made under exactly the same conditions and at the same time as those that were unfrozen, and were selected at random from the number.

The appearance of the frozen briquettes after being thawed and of the unfrozen was so nearly the same that they could not be distinguished. In the case of the natural cement mortar briquettes, the surface of the ones which had been frozen was usally disintegrated for a small depth, the briquettes being hard at the center; and those not frozen were firm throughout.

Portland Cement

The results in Table I show a decrease in strength of the frozen briquettes. The average loss due to freezing immediatly is 22 %. The percent of loss decreases between this time and when the time of freezing is five hours, at which time the percent of loss is ten - the smallest reached; - after this it again increases.

This variation shows that when cement mortar has set in a warm room for five hours and is then allowed to freeze, the action of the frost has sufficient strength to break the set, and the frozen briquettes then become as weak as if frozen in less than five hours.

The alternate freezing and thawing in Table II shows a large loss in strength. Table III differs from Table I in that the briquettes were allowed to stand but one day in a warm room after being frozen. A comparison of the percent of loss of these two tables will show that the briquettes gradually regain their strength.

Natural Cement.

The effect of alternate freezing and thawing natural cement mortar is shown in Table IV. The Utica and Rosendale cements were completly ruined; when placed in water after being frozen, they crumbled to pieces. The Louisville Globe gave some strength after having been frozen. The conditions of freezing the briquettes of Table V and VI were the same, but the briquettes of Table V were allowed

to stand in a warm room for three weeks after having frozen for one week, while those of Table VI were allowed to stand but one day. It is seen that the natural cement regains its strength very fast when having been frozen continually for a time and then being placed in a warm room.

Conclusion

From the results given in the foregoing tables, there is no doubt but that freezing injures cement mortar at first; but it may regain its strength after a time and even finally become stronger.

The rate of this increase in strength for the Portland cements is about 2⅔ percent per week, while for the natural cement this percent is about fourty for the Louisville Globe, and some smaller for the Utica and Rosendale.

Continual freezing of cement mortar for several days does less damage than alternate freezing and thawing.

In the case of continually freezing Portland cement mortars for at least four days, the loss is small and its strength

will be regained in a few weeks. The loss in alternate freezing and thawing is large, but its strength is not always completly lost, and will probably regain strength after a time.

Alternate freezing and thawing completly ruined the Utica and Rosendale cement mortar, but the Louisville Globe gave some strength, although the loss caused by continual freezing was soon regained when placed in a warm room.

The Utica cement is the most sensative to freezing, for in many cases the frozen briquettes gave no strength and those that did survive were very weak. The Louisville Globe was the least sensative to freezing of the natural cements used. Its loss was not great, and it soon regained its strength and even more.

Thus it is seen that natural cement mortar should not be used in freezing weather unless there is a continual freezing; while Portland cement may be used with but little loss.

— END —